Materials for High Temperature Applications

Kameleshwar Upadhya

Raytheon ITSS Air Force Research Laboratory AFRL/PRSM 10 E. Saturn Blvd. Edwards AFB, CA 93524-7680

June 2001

Final Report

20010906 013

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.



AIR FORCE RESEARCH LABORATORY AIR FORCE MATERIEL COMMAND EDWARDS AIR FORCE BASE CA 93524-7048

NOTICE

When U.S. Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise, or in any way licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may be related thereto.

FOREWORD

This Final Technical Report was prepared by Raytheon ITSS, Lanham, MD, under Contract F04611-93-C-0005, for the Air Force Research Laboratory (AFRL), Edwards AFB, CA. The Project Manager for AFRL was Mr. Carl Ousley.

This report has been reviewed and is approved for release and distribution in accordance with the distribution statement on the cover and on the SF Form 298.

CARL E. OUSLE

Project Manager

STEVEN A. SVEJDA, MAJ. USAF

Chief, Propulsion Materials

Applications Branch

PHILIP A. KESSEL

Technical Advisor, Space and Missile

Propulsion Division

RANNEY G. ADAMS III

Public Affairs Director

REPORT DOCUMENTATION PAGE OMB No. 0704-0188 Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS. 3. DATES COVERED (From - To) 2. REPORT TYPE 1. REPORT DATE (DD-MM-YYYY) 01 Nov 1993 - 04 Dec 1997 Final Report 26-04-2001 5a. CONTRACT NUMBER 4. TITLE AND SUBTITLE F04611-93-C-0005 5b. GRANT NUMBER **Materials for High Temperature Applications** 5c. PROGRAM ELEMENT NUMBER 62601F 5d. PROJECT NUMBER 6. AUTHOR(S) 3058 5e. TASK NUMBER Kameleshwar Upadhya RF5C 5f. WORK UNIT NUMBER 346069 8. PERFORMING ORGANIZATION 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) REPORT NUMBER Raytheon ITSS Air Force Research Laboratory AFRL/PRS 10 E. Saturn Blvd. Edwards AFB CA 93524-7680 10. SPONSOR/MONITOR'S 9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) ACRONYM(S) Air Force Research Laboratory (AFMC) 11. SPONSOR/MONITOR'S REPORT AFRL/PRSM NUMBER(S) 10 E. Saturn Blvd. AFRL-PR-ED-TR-2001-0022 Edwards AFB CA 93524-7680 12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited. 13. SUPPLEMENTARY NOTES 14. ABSTRACT Investigation of the processing of a variety of high temperature materials was accomplished. Nanocrystalline silicon nitride powders were synthesized and hot isostatic pressed to produce material at 97% theoretical density after sintering. 15. SUBJECT TERMS high temperature materials; thermal protection systems; carbon-carbon composites; refractory metals; nanocrystalline materials: nanophase powders 19a. NAME OF RESPONSIBLE 17. LIMITATION 18. NUMBER 16. SECURITY CLASSIFICATION OF: OF PAGES PERSON OF ABSTRACT Dr. Carl Ousley 19b. TELEPHONE NUMBER (include area a. REPORT b. ABSTRACT c. THIS PAGE 5 Α

Unclassified

Unclassified

Unclassified

(661) 275-6346

Form Approved

TABLE OF CONTENTS

SECTION	PAGE
SUMMARY	1
REFERENCES	2

SUMMARY

Work performed under the high temperature materials development task of the in-house Basic Research in Rocket Propulsion contract carried out at the Air Force Research Laboratory, Propulsion Directorate, Edwards Air Force Base, California is documented here by reference to the relevant technical papers, presentations, and patents that were produced.

REFERENCES

JOURNAL PAPERS

Upadhya, K. and Hoffman, W. P., "Advanced Composite Microtubes for Microelectromechanical Systems", *JOM*, 46, 54 (1994)

Upadhya, K., "High Performance TiC Coatings By Plasma Enhanced Deposition", JOM, 12 (1995)

Upadhya, K., Hoffman, W.P. and Rodgers, S.L., "Synthesis and Hot Isostatic Pressing of Nanocrystalline Silicon Nitride Powder, *J of Materials Synthesis and Processing*, **5**, 141 (1997)

Upadhya, K., Yang, J.M., and Hoffman, W.P., "Advanced Materials for Ultrahigh Temperature Structural Applications Above 2000° C." Am Cer. Soc. Bul., 76, 51 (1997)

PATENTS

"Densification of Porous Articles by Plasma Enhanced Chemical Vapor Infiltration" Upadhya, K. and Hoffman, W.P., US Pat. No. 5468357 (11/21/95)

"Tungsten-Copper Composite Material with Rhenium Protective Layer, and its Preparation", Upadhya K., US Pat. No. 5705283 (1/06/98)

CONFERENCE PROCEEDINGS

Upadhya, K., "Advanced Composite Materials for Aerospace Applications-A Critical Review", High Performance Metal and Ceramic Matrix Composite Materials Conference Proceedings, TMS, Warrendale, PA, USA, 1994

Upadhya, K., "Plasma Synthesis and Processing of Novel Ceramic and Ceramic -Matrix Composite Materials", *High Performance Metal and Ceramic-Matrix Composite Materials Conference Proceedings*, TMS, Warrendale, PA, USA, 1994

Upadhya, K., "High Performance Metal and Ceramic-Matrix Composite Materials", TMS, Warrendale, PA, 1994

Upadhya, K., "Plasma Synthesis of Novel Ceramic Materials, Proc. on High Performance Materials for Rocket Engines and Space Applications", TMS, Warrendale PA, 1995

K. Upadhya, "Development in High Temperature Materials- A Critical Review" *High Performance Materials for Rocket Engines and Space Applications Proceedings*, TMS, Warrendale PA, 1995

Upadhya, K., "High Temperature High Performance Materials for Rocket Engines and Space Applications", Conference Proceedings, held in November 1994, Chicago, IL, Pub. TMS, Warrendale, PA, 1995

AFRL-PR-ED-TR-2001-0022 Primary Distribution of this Report:

AFRL/PRSM (5)
Carl E. Ousley
10 E. Saturn Blvd.
Edwards AFB CA 93524-7680

Dr. David Campbell (2) ERC Air Force Research Laboratory AFRL/PRSM 10 E. Saturn Blvd. Edwards AFB CA 93524-7680

Dr. Wes Hoffman (3) AFRL/PRSM 10 E. Saturn Blvd. Edwards AFB CA 93524-7680

AFRL/PR Technical Library (3) 6 Draco Drive Edwards AFB CA 93524-7130

Chemical Propulsion Information Agcy (1) Attn: Tech Lib (Dottie Becker) 10630 Little Patuxent Parkway, Suite 202 Columbia MD 21044-3200

Defense Technical Information Center (Orig.+1) Attn: DTIC-ACQS (Acquisitions) 8725 John J. Kingman Road, Suite 94 Ft. Belvoir VA 22060-6218